# Closely-Spaced Parallel Approaches

Application Description

RTCA SC-186

Version 1.2

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## Overview

The Closely-Spaced Parallel Approach (CSPA) application is an operational, procedures-based concept, along with appropriate supporting technologies, for conducting independent, simultaneous approaches to closely-spaced parallel runways in meteorological conditions requiring instrument approaches. The application may be used for runways spaced from 2,500 ft. to 4,300 ft. The objective is to maintain an arrival rate similar to that achievable in visual meteorological conditions when visual approaches may be conducted.

**Closely-Spaced Parallel Approaches**

## 1.1 ***Introduction***

### 1.1.1 Background

In recent years, airport runway construction within the United States has not been able to keep pace with the rise in traffic growth; resulting in an increase in both the number and duration of flight delays. Many U.S. airports depend on parallel runway operations to meet the growing demand for day-to-day operations. In the current airspace system, poor weather conditions reduce the capacity of closely-spaced parallel runway operations. These capacity losses can result in landing delays causing inconveniences to the traveling public, interruptions in commerce, and increased operating cost to the airlines.

The Closely-Spaced Parallel Approach (CSPA) application is an operational, procedures-based concept, along with appropriate supporting technologies, for conducting independent, simultaneous approaches to closely-spaced parallel runways. For suitably equipped aircraft with eligible crews, CSPA is very similar to today's typical instrument approach operations. The application only becomes truly obvious to the flight crew when an extremely unusual event occurs: one aircraft flies off-path and threatens the safety of another.

The CSPA application focuses on two aspects of the closely-spaced parallel approach problem. First, approach paths must be designed and flown such that the possibility of one aircraft on one approach interfering with another aircraft on the other approach is remote. Second, if this remote event does occur, a means must be provided that will allow the non-offending aircraft to safely avoid the intruding aircraft.

The application described in this section is the result of collaborative work completed over the last few years by the Closely-Spaced Parallel Approaches Sub-group of RTCA SC-186 WG-1, that attempted to integrate research results into a meaningful operational concept. Several studies of the CSPA concept have been completed by NASA, the FAA and others [1-8]. However, elements of the concept described here still remain to be verified.

### 1.1.2 Operational purpose

The objective of Closely-Spaced Parallel Approaches (CSPA) is to allow simultaneous independent approaches to closely-spaced parallel runways in IMC and thereby maintain an arrival rate close to that achievable in better weather when visual approaches can be conducted.

### 1.1.3 Domain / Environment

CSPA is applicable to the final approach phase of flight when instrument approaches are in use at capacity limited major airports with closely-spaced parallel runways. Early CSPA implementation will be in Class B or Class C airspace, in a terminal radar control environment. It is expected that CSPA will be applicable to runways spaced between 2,500 and 3,400 or 4,300 ft. The lower limit on runway spacing is determined by wake vortex considerations. For runways spaced 3,000 ft. and greater, the Precision Runway Monitor (PRM) may be utilized to achieve independent simultaneous approaches. Without PRM, CSPA could be used to permit independent approaches to runways spaced less than 4,300 ft., the current lower limit for simultaneous independent approach operations. For runways spaced less than 2,500 ft, a concept called the Paired Approach Application, which addresses the wake vortex issue, may be implemented, provided that this concept is further developed and validated [15]. Ground-based controller decision support tools may facilitate sequencing and positioning aircraft for CSPA, but this has not been investigated.

The CSPA application begins when the final approach course has been established and the aircraft are cleared for the approach. It normally concludes when the aircraft lands In the event of a missed approach, the CSPA application continues until the aircraft is established on a missed approach course that diverges from the parallel runway and ATC is able to provide instructions to the aircraft to maintain separation from all traffic.

The CSPA application will be limited to appropriately equipped aircraft with trained flight crews.

### 1.1.4 Justification

CSPA is intended as a capacity enhancement, enabling independent closely-spaced parallel runway operations in visibility conditions when instrument approaches must be used. At present, airline schedules are predicated on arrival rates achievable only in clear weather, when visual approaches are used. When weather conditions dictate the use of instrument approaches, arrival rates decrease, resulting in delays. The primary beneficiaries of CSPA will be the airlines and the traveling public. Other beneficiaries include airports where a new runway need not be constructed to meet increasing demand; or if a new runway is required, it can be built much closer to existing runways for the equivalent capacity increase.

CSPA must produce significant operational improvements, in terms of airport arrival rate (or maintaining scheduled operations for airlines) to justify the expense of equipping the aircraft. Further analysis is required to demonstrate the feasibility and cost effectiveness of the CSPA solution. The extension of the concept to offset or curved approaches for runways spaced too close for straight-in approaches will vastly increase the economic viability of CSPA as it will allow CSPA to be utilized at many more airports in the US. A preliminary analysis of CSPA benefits at existing U.S. airports is provided in [14].

The cost savings associated with building a new runway up to 1,800 ft closer to an existing parallel runway where independent simultaneous approaches are to be conducted will be considerable, and potentially more significant than the capacity gains at present airports. The benefits of new closer runway construction are difficult to quantify and are dependent both on future demand and on future environmental restrictions on airport development, including noise issues.

CSPA implementation depends not only on a favorable cost/benefit analysis to justify the equipage costs, but also on minimizing changes to present airspace rules and operating procedures. It also currently depends on achieving near fleet-wide equipage to support independent parallel approaches at each airport where CSPA operations are to be conducted. PRM trials have shown that unless a very high percentage of aircraft are accepting the approach, no significant capacity gain is realized. A possible alternative to fleet-wide equipage would be segregating equipped aircraft from non-equipped aircraft through use of ground-based controller decision support tools.

The implementation of other ADS-B/CDTI applications will also impact the viability of CSPA. As more applications are implemented, the incremental cost of each application will be reduced, making each application more cost effective.

There may be additional safety benefits from CSPA in visual conditions, especially at night or when visual conditions are marginal, although this has not been quantified.

### 1.1.5 Maturity and user interest

NASA Langley developed and conducted preliminary evaluations of alerting algorithms and traffic displays they referred to as Airborne Information for Lateral Spacing (AILS). A full mission flight deck simulation study was completed in 1998 [7]. This study used actual flight hardware (a TCAS unit augmented with AILS software) that implemented the concept described in [11]. Operational procedures, flight crew procedures, and a candidate training outline are provided in [7]. Evaluation metrics were based on PRM requirements [13], and were primarily to validate the results of previous analytical studies when applied to a pilot-in-the-loop test. The results of this test validated both the analytical results and the design assumptions of the alerting algorithm.

NASA Langley and Honeywell performed a full mission flight validation [8] using certified flight hardware with non-certified CSPA software which was modified from the AILS algorithms. Two aircraft were equipped for this test, with one aircraft always acting in the role of the intruder aircraft. This flight test was designed to validate the 1998 simulation results, in a flight environment using ADS-B equipment. Results from this flight evaluation were found to substantiate the previous results and validate the airborne portion of the operational concept.

A full mission air/ground simulation, including the role of ATC in conducting the approach, was conducted at NASA Ames in 2000 [17]. Results from this study were also favorable, but identified additional research issues as noted in Section 1.5. Airlines and avionics manufacturers have shown interest, as evidenced by their support of the research efforts and flight test, as well as participation in the CSPA sub-group of SC-186, WG-1.

Safety studies of the CSPA application have been conducted by the FAA [1] which indicate the viability of the concept and that safety levels comparable to PRM can be achieved.

The current CSPA concept is also in part derived from earlier research conducted in support of PRM. In particular, the “worst case blunder” was evaluated and defined for PRM to be a 30 deg. heading change towards the parallel traffic. Additional studies by MITRE CAASD have shown true blunders of any kind made by traffic on approach to parallel runways to be exceptionally rare events, in fact so rare that a reliable prediction of their frequency cannot be made [16].

## 1.2 *Operational concept, roles, and procedures*

### 1.2.1 Concept description

The concept requires accurate navigational guidance for the approach phase of flight. This may be provided by a precision GPS-based Landing System (GLS) such as WAAS or LAAS, or any other system that meets the navigation performance requirements to ensure aircraft will remain on their assigned approach trajectory. A surveillance capability is provided by each aircraft communicating a position estimate, derived from differential GPS (DGPS) position (or equivalent), to all aircraft approaching the parallel runways via a data exchange capability such as ADS-B.

In the envisioned procedure, each equipped aircraft will, as in today’s operation, accurately manage its flight path along the approach course and thereby maintain separation from traffic on the parallel runway. A guiding principle of the CSPA concept is to minimize the probability of the aircraft deviating from the approach course (referred to as a blunder). This is achieved by providing an accurate navigation capability, display of navigational information and path deviation alerting should the aircraft not maintain its assigned approach trajectory.

Depicting the parallel approach path, and the traffic on the parallel approach on the Navigation Display (ND) may be advantageous in enhancing flight crew traffic situation awareness. In this case, a reduced range will be needed, since present ND minimum ranges are 5 or 10 miles. The traffic being tracked by CSPA should be identified from other traffic.

In the event that one aircraft deviates from its assigned approach path, trajectory and conflict prediction algorithms provide visual and auditory alerts to notify the deviating aircraft and its traffic of the off-course situation. If the deviating aircraft fails to return to course, and “blunders” towards the parallel traffic, it will be required to execute a breakout maneuver, turning away from the parallel approach course. If the blundering aircraft still fails to respond, and threatens an aircraft in the parallel stream, the threatened aircraft is provided with a break out command and will execute a climbing turn away from the threatening aircraft. After the flight crew have the aircraft established on the breakout procedure and are avoiding the blundering aircraft, they will contact ATC who will then issue vectors to begin another approach in exactly the same manner as missed approaches are currently handled.

It should be stressed that the primary function of the CSPA concept is to provide separation assurance through accurate flight path management. Only in the rare event of a breakdown of this separation assurance function, when an aircraft has blundered off course, is threatening another aircraft, and is not responding to instructions to change course, does the primary requirement become collision avoidance. The current CSPA concept is based on previous analytical studies, and consists of a single breakout procedure, a climbing $45^0$ turn at go-around power away from the parallel approach path. The single maneuver is much the easiest for the flight crew of the escaping aircraftto effect quickly and accurately, but it may not be the most efficacious for all blunder trajectories. The requirement for changing the maneuver in the event that it is not producing divergence between the aircraft has also not been investigated. The overall effectiveness of this maneuver in achieving the target level of safety needs to be further evaluated [1], as does its applicability to the actual airspace at airports with closely-spaced parallel runways. It is anticipated that blunders necessitating another aircraft to abandon its approach will be extremely rare events, almost certainly less than one in a million approaches. Blunders on instrument approaches are extremely infrequent in present airspace [13] and should be even less frequent with LAAS, WAAS and similar GLS-based approaches.

The CSPA application is most closely aligned with the Airborne Separation Category of ASAS applications as defined in the Principles of Operation for Airborne Separation Assistance Systems (PO-ASAS) [18]. Separation responsibility for aircraft on the parallel approach is transferred to each aircraft conducting the approach. ATC maintains separation responsibility for aircraft approaching the same runway (i.e. the in-trail spacing). Separation responsibility for aircraft on the parallel approach is transferred when the aircraft accepts the approach clearance. CSPA aircraft are tracked automatically by the CSPA system, and thus do not need to be specifically identified by ATC, as is usual with Airborne Separation Category applications. All separation responsibility returns to ATC when the aircraft lands, or when ATC accepts the aircraft back into radar-based separation coverage after initiating either a missed approach or breakout maneuver. Separation responsibility in the event of a breakout maneuver is similar to TCAS in that once a Resolution Advisory occurs, the pilot has responsibility to execute the commanded maneuver.

Note that since aircraft in the two parallel streams are likely to have different approach speeds, any aircraft may be overtaken by another aircraft in the parallel stream, requiring the surveillance function to be active for more than one aircraft.

### 1.2.2 Procedures and responsibilities

#### 1.2.2.1 Air traffic control

ATC will have information on which arriving aircraft are CSPA-equipped, and should not offer CSPA to unequipped aircraft. ATC vectors CSPA aircraft to the final approach course and then manages in-trail separation between aircraft in each parallel approach stream as well as separation from other aircraft not on final approach to the parallel runways.

When the aircraft are cleared to conduct the published approach, and accept the approach, standard terminal separation between the aircraft on the parallel approaches is discontinued, as with most approaches today. The airborne systems now provide surveillance, monitoring and alerting for traffic on the parallel approach path.

The airspace and approach design should provide sufficient separation from arriving and departing traffic to ensure that, in the event of a blunder, the blundering aircraft (and, if an escape maneuver is commanded, the evading aircraft) has adequate time to contact ATC. This type of airspace and approach design will allow the flight crew to handle the emergency condition without the added time pressure of immediately contacting ATC for instructions.

As with present procedures for instrument and visual approaches, ATC may issue instructions for any or all aircraft on the final approach course to execute a missed approach. ATC may also, as needed, issue other maneuvers that abort the approach, but should not normally issue instructions for a turn towards the parallel traffic.

To maximize the benefit derived from CSPA, arriving aircraft should be appropriately spaced to provide an arrival rate equal to the acceptance rate for the approach. Additionally, either nearly all arriving aircraft must fly CSPA, or some means must be found of grouping aircraft that will fly the approach from those unable to do so, or the maximum capacity gain will not be realized.

Sequencing and spacing arriving aircraft to support CSPA operations could be facilitated with controller decision support tools such as CTAS TMA, which will provide the appropriate arrival rate into the TRACON, although the benefit gained has not been evaluated. TMA could also be adapted to segregate equipped aircraft that will conduct CSPA from those that have declined the approach. Having the aircraft utilize FMS arrival routes would further support the controller in positioning and spacing aircraft for the approach. However, given normal wind and performance variations, to achieve the optimum spacing this may require four dimensional routes (i.e. including a required time of arrival (RTA) at the point at which the aircraft should be cleared for the approach). An alternative to FMS approaches would be a controller tool such as the CTAS Final Approach Spacing Tool (FAST), which would allow the controller both more flexibility and predictability in sequencing the arrivals.

#### 1.2.2.2 Flight Crew

CSPA will involve specific flight crew training and currency requirements, including approach procedures and familiarization with the breakout procedure. ATIS will inform flight crews that “closely-spaced parallel approaches are in operation”, and participation will be voluntary. Flight crews will confirm that CSPA is operational and will advise the arrival controller if they are unable to accept CSPA. The CSPA operation must be briefed, with particular attention to the breakout maneuver and the Decision Height. The flight crew will also determine the appropriate ND ranges for both pilot flying (PF) and pilot not flying (PNF). To maintain RNP, and not trigger false alerts, it is probable that the approach will need to be flown auto-coupled, and failure or unintended disconnect of the auto-pilot may require execution of the published missed approach procedure.

Flight crews will accept ATC instructions for vectoring to the final approach course, or will fly an FMS route as discussed above. Aircraft will be cleared for CSPA only when they are lined up on the final approach course and have CSPA active. Once established on the final approach course, and with CSPA active the flight crew should acknowledge the approach clearance. This acknowledgement constitutes acceptance of separation responsibility for any traffic on the parallel approach. Terminal separation requirements are then discontinued. Separation is maintained by adherence to the approach path and the flight crews’ primary responsibility is to monitor the appropriate aircraft systems and determine that they arewithin the boundaries of the approach path at the appropriate RNP. Should an aircraft blunder off the approach trajectory, then separation has failed, and the primary action becomes collision avoidance.

In the event of a missed approach, initiated either by ATC or by the flight crew, the published missed approach is flown until ATC issues a new instruction, just as with current approach procedures. Missed approaches for both parallel runways that support CSPA will include a turn away from the parallel runway (initiated at the missed approach point) to provide sufficient lateral separation and divergence between aircraft on the parallel approaches for ATC to resume complete separation authority.

In the event of CSPA alerts being issued, the flight crew is expected to quickly implement the appropriate response to the alert. Alerting and display features provide flight crew awareness of ownship and traffic position relative to the approach path. Aircraft deviations must pose a threat to another aircraft before a warning is issued that requires the approach to be abandoned (i.e. the breakout maneuver to be performed). Either aircraft can be the cause of alerts, or the recipient of alerts caused by the other aircraft.

Alerts for this procedure have two levels; cautions and warnings. Cautions tell the flight crew to heighten their awareness of the evolving traffic situation, similar to a TCAS TA. An own-ship caution indicates the own-ship is deviating from the approach path and requires immediate corrective action. A warning, both for own-ship and traffic blunder, requires the flight crew to immediately disconnect the auto-pilot, and hand fly the breakout maneuver, a 45 deg. climbing turn at go-around power away from the parallel approach course. Breakout maneuver guidance may be provided on the PFD and/or the ND, but the requirement for this has not been verified, although in the Ames simulation, flight crews suggested this information would be needed.

The normal sequence for alerts is first cautioning the deviating aircraft to return to course, followed by cautioning any threatened aircraft on the parallel approach. If the deviating aircraft does not return to course, and continues to threaten the adjacent traffic, it is commanded to execute the breakout maneuver, turning away from the threatened aircraft. Finally, should the threatening aircraft fail to execute the breakout, then the threatened aircraft is commanded to perform the break out maneuver, turning away from the threatening aircraft. The alert “threshold”, i.e. the projected time to closest point of approach is given in Table 1.

Once the aircraft is established on the breakout procedure heading and at breakout procedure target speed, the auto-pilot may be re-engaged. The flight crew should contact ATC when able for further instructions. The breakout procedure will be depicted on the CSPA chart.

Where practical, the initial heading of the missed approach procedure should be identical to the breakout maneuver, since this will impose the minimum requirements on the flight crew. Breakout maneuvers commanded in response to a blundering aircraft are expected to be extremely rare, and most pilots would fly their whole careers without ever executing one other than in simulator training. However, the overall safety level achieved by CSPA will depend on the flight crew correctly and quickly effecting the breakout maneuver when commanded. Pilot reaction time to, and compliance with this exceptionally rare but critical maneuver needs further investigation.

It is expected that missed approaches will be much more frequent than blunders or system failures necessitating breakout maneuvers, just as is the case with current approach procedures. This means that the CSPA concept has to deal as safely and efficiently with missed approaches as in present airspace, even though the aircraft will initiate the missed approach procedure at separations below current ATC standards. The possibility of blunders during missed approaches must be considered.

Since transport category aircraft do not normally initiate a turn while below 400 ft above ground, CSPA may require a Decision Height of 400ft. to permit aircraft to maneuver for a breakout procedure at DH. The requirement for increased DH needs to be investigated.

The PNF’s task is to provide approach monitoring for the PF, do radio communications, comply with normal approach procedures, and maintain primary CSPA traffic awareness by utilizing the ND at the range the flight crew have previously agreed is suitable for traffic viewing. This range can be variable, depending on proximity to traffic and other factors, such as progress along the approach path. The PF is expected to maintain the traditional duties and to keep the ND range to that which provides the best overall approach environment situational awareness. At the D H, and with the runway in sight, the PF decides whether it is safe to continue to a landing.

#### 1.2.2.3 Airline Operations

N/A

#### 1.2.2.4 Flight Service Stations

N/A

### 1.2.3 Proposed new phraseology

TBD

### 1.2.4 Aircraft separation / spacing criteria

Several studies have examined the CSPA separation criteria. The CSPA concept for a 3400 ft runway separation with various levels of pilot reaction time and alerting thresholds using the 1996 version of the NASA AILS alerting algorithm was analytically examined in [1]. The CSPA algorithm at 3400ft and 2500ft runway separations was examined in [10]. Interestingly, this latter study showed that while the measured system performance was acceptable, miss distances were lower (worse) for the 3400 ft cases. Tests conducted at NASA Langley [7 and 8] showed that CSPA operations are feasible at runways separated by 2500 ft. Extensive testing below 2500 ft separation has not been conducted since closer operations are restricted by wake vortex considerations. Longitudinal (in-trail) separation standards remain unchanged.

The aircraft separations that trigger alerts for the Langley AILS algorithms are provided in Table 1 below. These separations are based on the Langley concept of rotating both approaches 2 deg. away from each other so the localizers do not intersect at the start of the approach.

| Alert state | Alert level | Alert area threshold, ft, for --- | | | Alert time threshold (sec) |
|---|---|---|---|---|---|
| | | Lateral | Longitudinal | Vertical | |
| Path | Caution | 1800 | 5000 | 1800 | 30 |
| Path | Warning | 1250 | 3400 | 1250 | 21 |
| Traffic | Caution | 1300 | 3500 | 1300 | 22 |
| Traffic | Warning | 900 | 2500 | 900 | 16 |

Table 1. Alert Thresholds

See the “Display & Interface” section below for more description of the alert levels.

### 1.2.5 Sample scenarios

TBD

## 1.3 **Requirements**

### 1.3.1 Display & Interface / Functional

The airborne components required for this system are a DGPS-based landing system (or equivalent), aircraft-to-aircraft data link using ADS-B, and CSPA alerting functions. ADS-B communications are used to broadcast highly accurate information between aircraft on the parallel approach paths.

For the NASA research efforts, operational procedures and supporting equipment were defined to minimize crew operational changes or changes to airborne equipment. The 1998 CSPA flight test [8] used “off the shelf” equipment to implement CSPA in two test aircraft. Custom software was added to the TCAS units to implement CSPA, and pilot display additions were provided on the standard TCAS display interface channel. The NAV Display was provided with a 10X switch to allow the flight crew to set an appropriate range to make both approach paths visible.

CSPA alerting is divided into two alerting sets: “path” alerting for own-ship causing a potential collision situation and “traffic” alerting for own-ship being threatened by another aircraft. In addition, each of these sets are divided into a two-stage alert. For the path alert, a caution alert is provided when own-ship’s maneuver is causing a possible collision. A subsequent warning alert is provided when own-ship’s maneuver is causing a probable collision. A similar sequence is provided for traffic alerts. This two-stage alerting is significant in obtaining operationally reasonable pilot responses to CSPA alerting. Using this scheme, warning alerts, requiring a breakout maneuver, are never “surprises” to the flight crew; warning alerts are always preceded by caution alerts. The CSPA alerts used in the NASA Langley research are shown in Table 2 below.

| Alert state | Alert Level | Representation | | Description |
|---|---|---|---|---|
| | | Visual* | Audio | |
| Localizer | Advisory | LOCALIZER | | Ownship is off centerline by one half path width (traditional one half full-scale error on lateral deviation indicator) |
| Localizer | Caution | LOCALIZER | | Ownship is off centerline by full path width (traditional full-scale error on lateral deviation indicator) |
| Path | Caution | PATH | Path parallel approach | Ownship performance producing possible collision situation |
| Path | Warning | CLIMB TURN | Climb turn | Ownship performance producing probable collision situation |
| Traffic | Caution | TRAFFIC | Traffic parallel approach | Ownship being threatened with possible collision |

| | | | | |
|---|---|---|---|---|
| Traffic | Warning | CLIMB TURN | Climb turn | Ownship being threatened with probable collision |

Table 2. Alert Sequence

* Visual alerts are color coded as follows:
Caution: amber
Warning: red

To support the CSPA concept, the flight deck displays should perform the functions listed below. In this list the items preceded by an asterisk (*) are regarded as requirements, the other items are recommended but their exclusion is not expected to impede the safe operation of the system. The display should:

*1. Provide a positive indication of when the CSPA system is operating.
*2. Provide a positive indication for system malfunction or degraded operation.
*3. Show the traffic being monitored.
4. Show the ownship approach path.
5. Show progress along the nominal approach path.
6. Show the relative position of traffic.
*7. Present an alert for ownship off-path operation.
*8. Present a warning alert when ownship violates its airspace boundaries.
*9. Enable monitoring parallel traffic for threatening conditions.
*10. Support the monitoring of multiple airplanes along the close parallel runway approach path.
11. Present an alert for the potential loss of lateral separation.
*12. Present a breakout command with a warning traffic alert.
13. Present an indication of the EEM turn heading.
*14. Provide a means to reset the alerts.
*15. Provide aural alerts for abnormal conditions per SAE ARP1402/4.
*16. Use SAE ARP1402/4 color and format standards in presenting alerts.
17. Identify the traffic being monitored.
*18. Provide a clear indication of the cause of the alert so that corrective action can be taken.
*19. Clearly distinguish the CSPA alerts from other alerts.

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## 1.3.2 Infrastructure Requirements

### 1.3.2.1 Ground / ATC

GLS (or equivalent) technology, is required to provide a precise path to the runway. Current angular-based precision approach systems, such as Instrument Landing Systems (ILS), indicate angular deviations from runway centerline and provide an approach corridor 3 to $6^0$ wide (the localizer geometry). For runways spaced 2,500 ft apart, the localizer beams will overlap about 5-6 miles from the approach end of the runways, depending on runway length. This makes the typical ILS geometry unsuitable for CSPA without modification. One possible modification would be to define the allowable deviation (RNP) from the centerline of the ILS as much less than current full-scale deflection, thereby eliminating the overlap. Another method would be to rotate the localizer centerline for the secondary runway away from other approach so the inner portions (2 dots of deviation) are parallel to each other. While this method will require a penalty in increased Decision Height for the secondary runway, it will allow normal operations to the primary runway, which provides several operational benefits.

If a GLS is used, “capturing” the final approach course while maintaining adequate separation between the approaches would be facilitated by the capability of GLS to provide curved or offset guidance to the final approach course. GLS can be used for offset final approach courses allowing the CSPA concept to be similarly extended.

Based an anecdotal data from the 1998 CSPA flight demonstration, ATC personnel may need aircraft identification data for aircraft generating CSPA alerts. If the CSPA alert state is in the ABS-B message, a ground-based ADS-B receiver and a simple ATC display may suffice for equipment augmentation. Further studies with defined ATC procedures for CSPA operations will be needed to further define ATC requirements.

#### 1.3.2.2 Aircraft

The goal of CSPA is to maintain a safety level that is equal to or better than that of the current ATC system. To provide this level of safety, both the frequency and the accuracy of the breakout maneuver must be controlled. The former is needed to ensure that the number of breakout maneuvers is very low and to ensure the CSPA system provides the necessary improvement in aircraft arrival rate. The breakout maneuver itself must be robust enough to insure that, when the rare breakout maneuver is necessary, the FAA defined near miss distance of 500ft. is rarely compromised.

The objective of the NASA Langley AILS research was to design the CSPA system so that the joint probability of the occurrence of a breakout maneuver and the breakout maneuver being unsuccessful (i.e. an NMAC occurs) is less than $10^{-9}$. This was achieved by initial design of the system so the probability of a breakout maneuver is no more than $10^{-7}$ for each approach, while the probability of an unsuccessful breakout maneuver is less than $10^{-3}$. The extra order of magnitude insures that the system will provide the necessary level of safety even if one of the components falls short of its design criteria. NASA Langley determined that each of the following CSPA system errors must be controlled to ensure the joint probability of a breakout maneuver occurrence does not exceed $10^{-7}$.

1. Navigational signal errors that cause an unnecessary breakout maneuver by either aircraft.
2. Mechanical problem in either aircraft that causes a unnecessary breakout maneuver.

3. Incorrect ATC clearance in which the controller causes a breakout maneuver by clearing either the aircraft for CSPA to the wrong runway, or vectors the aircraft through a final approach course.
4. Communication errors between ATC and either aircraft that result in an unnecessary breakout maneuver.
5. Pilot errors - situations in which the flight crew of either aircraft causes an unnecessary breakout maneuver by selecting the wrong CSPA frequency for the approach.
6. Tracking errors that cause a breakout maneuver. Either the flight crew or the autopilot can cause these tracking errors. Tracking errors include flight in the maximum crosswind and lateral wind shear that is authorized for the approach.
7. False-positive turn and climb alerts that result in an unnecessary breakout maneuver.

In order to ensure that the frequency of unsuccessful breakout maneuvers will be rare, the following CSPA system errors must be controlled so the cumulative probability of an unsuccessful breakout maneuver will be less than $10^{-3}$.

1. Signal error situations in which the ADS-B signals are either delayed or not received causing a Near Mid Air Collision (NMAC).
2. Aircraft mechanical error situations in which a mechanical problem in the alerting system of the evading aircraft causes an NMAC.
3. False-positive turn and climb alerts that result in an unnecessary breakout maneuver and an induced NMAC.
4. False-negative turn and climb alerts in which a breakout maneuver should have occurred regardless of the NMAC outcome.
5. True-positive turn and climb alerts in which an induced NMAC occurs even though the CSPA system reacted correctly. This includes, but is not limited to, situations involving conflicting alerts by multiple intruder aircraft, secondary turns by the intruder aircraft, and certain overtaking situations by the intruder.
6. True-negative turn and climb alerts in which an NMAC occurred even though no turn and climb alert was generated and the CSPA system worked correctly. This includes, but is not limited to, situations involving late maneuvering by the intruder aircraft or intruder angles greater than $30^0$.
7. Communication problems between ATC and the evading aircraft, causing an NMAC.
8. Pilot errors- situations in which the pilot is slow to react or makes an improper breakout maneuver, causing a NMAC. This includes, but is not limited to, slow reactions times, misinterpretation or confusion concerning the displays or alerts, slow roll or pitch rate, inadequate bank angle, and incorrect breakout maneuver heading or altitude.

A full description of the NASA Langley approach to defining performance requirements is given in [12].

Aircraft conducting CSPA operations may be in close enough proximity to activate TCAS alerts. To prevent these unwanted alerts, the NASA CSPA concept includes automatically inhibiting TCAS alerts between CSPA aircraft. Inhibiting TCAS alerts will only occur for those aircraft that are within the TCAS alert threshold, have verified DGPS (or equivalent) position and ADS-B message integrity, and are being tracked by

CSPA. Should a breakout or missed approach be initiated, TCAS alerting is then uninhibited. Release of the alert inhibition relative to cessation of the CSPA alerts needs further investigation, since it is desirable to avoid a TCAS alert while the aircraft is executing the initial portion of the breakout maneuver. TCAS remains active throughout the approach for all aircraft, only the alerting is inhibited between CSPA aircraft. TCAS may not be required for CSPA, but, if installed, will be operated normally in terminal airspace except when inhibited as described above. If the system is not achieving the required integrity, then a missed approach will be required. In this case TCAS alerts should be immediately un-inhibited.

#### 1.3.2.3 Airlines Operations Center & Flight Service Stations (if applicable)

N/A

### 1.3.3 Training requirements

The 1998 CSPA simulation study [7] used a two-hour training block for CSPA that mimicked a traditional airline training situation. Test subjects deemed that this two hour block (briefing and simulator training) was sufficient for the CSPA procedure.

## 1.4 *Other Considerations*

### 1.4.1 Relationship to other programs and future enhancements

The potential for conducting CSPA operations in conjunction with other ADS-B applications, such as Final Approach and Runway Occupancy Awareness (FAROA) or self-spacing has not yet been considered. However, compatibility of the CSPA application with other applications will need investigation.

The Airborne Conflict Management system will accept input from other applications directing ACM to either turn off Conflict Detection and Conflict Prevention or to set the size of the Conflict Detection Zone to a specified size for specified target(s). CSPA will send the necessary information to ACM to inhibit ACM for aircraft involved in the CSPA operation.

## 1.5 *Other issues*

Issue: Is breakout maneuver consisting of single 45 deg. climbing turn the best option?

Priority: high
Resolution Method: analysis and simulation
Status: open

Resolution:

Issue: Requirements for ATC to resume all separation authority after a missed approach.

Priority: high
Resolution Method: analysis and simulation
Status: open

Resolution:

Issue: ATC separation responsibility during CSPA operations.

Priority: high
Resolution Method:
Status:

Resolution:

Issue: ATC role in CSPA if breakout maneuver has not been commanded.

Priority: high
Resolution Method:
Status:

Resolution:

Issue: Requirement for and benefits of controller decision support tools to set up for the approach.

Priority:
Resolution Method:
Status:

Resolution:

Issue: Requirement for and benefits of FMS approach to set up for CSPA.

Priority:
Resolution Method:
Status:

Resolution:

Issue: Requirement for flight crew to verify CSPA systems are working before approach can be conducted.

Priority:
Resolution Method:

Status:

Resolution:

Issue: Requirement for integrity monitoring for CSPA systems.

Priority:
Resolution Method:
Status:

Resolution:

Issue: Advisability of flying approach auto-coupled.

Priority:
Resolution Method:
Status:

Resolution:

Issue: Advisability of flying missed approach auto-coupled.

Priority:
Resolution Method:
Status:

Resolution:

Issue: Pilot compliance with initiating turn at Decision Height.

Priority:
Resolution Method:
Status:

Resolution:

Issue: Pilot reaction time to, and compliance with, escape maneuver command.

Priority:
Resolution Method:
Status:

Resolution:

Issue: Possibility of blunders during missed approach.

Priority:
Resolution Method:
Status:

Resolution:

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